

**Docket 7032
Exhibit DPS-VDH-3
54 Pages**

**POSITION PAPER ON ELECTRIC AND
MAGNETIC POWER FREQUENCY FIELDS AND
THE VELCO LAMOILLE PROJECT**

PREPARED BY

**VERMONT DEPARTMENT OF HEALTH
DIVISION OF HEALTH PROTECTION**

APRIL 11, 2005

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SUMMARY

Currently, there are no federal standards for occupational and residential exposure to electric and magnetic power frequency fields (“EMF”) nor are there standards or guidelines limiting EMF fields for appliance manufacturers at this time. Electric and magnetic power frequency fields refer to those fields produced by 60 Hertz power lines in this paper. The International Commission on Non-Ionizing Radiation Protection (ICNIRP) established guidelines for exposure of the public to magnetic and electric power frequency fields of 833 milligauss (mG) and 4.2 kilovolts per meter (kV/m), respectively [1].¹ The Institute of Electrical and Electronics Engineers’ (“IEEE”) magnetic power frequency field guideline for exposure to the public is 9,040 mG and 5 kV for the electric power frequency field [2]. Florida has established guidelines for power lines less than 230 kV of 150 mG and 2.0 kV/m at the edge of the right-of-way when the power line is operating at its highest continuous current rating [3]. The Florida guidelines are designed so that the maximum electric and magnetic power frequency fields will not exceed those fields produced by power lines now in operation and are not based on health effects. Germany (1997) adopted a national rule on EMF exposure for the general public limiting the electric power frequency field to 5 kV/m and the magnetic power frequency field to 1000 mG [4]. These fields are unlikely to be encountered in daily life. Typical magnetic power frequency fields in the home average 0.6 mG [5] and range from 0.1 to 4 mG [6] over a period of a day. Average electric power frequency fields in the home range from 0 to 0.01 kV/m [7].

For the purpose of the Vermont Department of Health’s (“VDH”) review of the Vermont Electric Power Company (“VELCO”) Lamoille Project, the New York and Florida guidelines were chosen for comparison because they provide the strictest guidelines presently available, even though they are not health-based. When the New York and Florida guidelines were exceeded, the ICNIRP guidelines, which are health-based, were compared with the projected magnetic or electric power frequency fields.

¹ All bracketed numbers throughout this Paper refer to the corresponding report in the References section.

Projected average loads with maximum line sag and maximum line to ground voltage were used for calculations of the electric and magnetic power frequency fields at the edge of the right of way for the proposed Lamoille Project. In summary, for average loading at the edge of the right of way, the Lamoille Project is expected to result in an increase in the magnetic power frequency field for the RCJ-18 corridor from 17 mG in 2006 to 21 mG in 2015; the RCJ-19 corridor increases from 3.6 mG in 2006 to 14 mG in 2015; the RCJ-20 corridor increases from 3.6 mG in 2006 to 20 mG in 2015; the RCJ-21 corridor increases from 17 mG in 2006 to 20 mG in 2015; the RCJ-22 corridor decreases from 17 mG in 2006 to 13 mG in 2015; and the RCJ-23 corridor increases from 4.4 mG in 2006 to 44 mG in 2015. The average projected magnetic power frequency field along the entire Lamoille Project corridor is approximately 22 mG in 2015, and ranges from 13 to 44 mG (refer to Appendix B Table 1 Columns “Existing Power Line-2006”, “Proposed Power Line-2006”, and “Proposed Power Line-2012”.) All of the projected magnetic power frequency fields along the entire proposed Lamoille Project corridor, as indicated above, are well below the Florida and ICNIRP guidelines.

In summary, for average loading directly under the power line, the Lamoille Project is expected to result in an increase in the magnetic power frequency field for the RCJ-18 corridor from 17 mG in 2006 to 22 mG in 2015; the RCJ-19 corridor increases from 9 mG in 2006 to 28 mG in 2015; the RCJ-20 corridor increases from 9 mG in 2006 to 28 mG in 2015; the RCJ-21 corridor decreases from 43 mG in 2006 to 28 mG in 2015; the RCJ-22 corridor decreases from 43 mG in 2006 to 13 mG in 2015; and the RCJ-23 corridor increases from 11 mG in 2006 to 44 mG in 2015. The average projected magnetic power frequency field directly under the power line for the entire Lamoille Project corridor is approximately 27 mG in 2015, and ranges from 13 to 44 mG (Refer to Appendix B Table 2 Columns “Existing Power Line-2006”, “Proposed Power Line-2006”, and “Proposed Power Line-2012”.) All of the projected magnetic power frequency fields along the entire proposed Lamoille Project corridor, as indicated above, are well below the Florida and ICNIRP guidelines.

In summary, for maximum continuous loading at the edge of the right of way, the magnetic power frequency field for the RCJ-18 corridor increases to a projected level of 417 mG with the Lamoille Project; the RCJ-19 corridor increases from an existing level of 33 mG to a

projected level of 177 mG the RCJ-20 corridor increases from an existing level of 33 mG to a projected level of 259 mG; the RCJ-21 corridor increases from an existing level of 57 mG to a projected level of 251 mG; the RCJ-22 corridor increases from an existing level of 57 mG to a projected level of 169 mG; and the RCJ-23 increases from an existing level of 57 mG to a projected level of 392 mG. (Refer to Appendix B Table 3 Columns “Existing Power Line-ROW Edge”, “Proposed Power Line-ROW Edge”.) The magnetic power frequency fields for a maximum continuous load at the edge of the ROW for both existing and proposed power lines for the Lamoille Project are less than the guidelines set by the ICNIRP. The projected magnetic power frequency fields for a maximum continuous load at the edge of the ROW along the Lamoille Project corridor are greater than the guideline set by Florida of 150 mG. It must be emphasized that the Florida guidelines are not health-based but are used by them to maintain the status quo. This demonstrates that the projected maximum magnetic power frequency fields for the Lamoille Project are well below the health based ICNIRP guideline.

In summary, for maximum continuous loading (higher than projected peak load) directly under the power line, the magnetic power frequency field for the RCJ-18 corridor increases to a projected level of 417 mG with the Lamoille Project; the RCJ-19 corridor increases from an existing level of 80 mG to a projected level of 358 mG the RCJ-20 corridor increases from an existing level of 80 mG to a projected level of 358 mG; the RCJ-21 corridor increases from an existing level of 140 mG to a projected level of 361 mG; the RCJ-22 corridor increases from an existing level of 140 mG to a projected level of 169 mG; and the RCJ-23 increases from an existing level of 140 mG to a projected level of 415 mG. (Refer to Appendix B Table 3 Columns “Existing Power Line-Directly Under”, “Proposed Power Line- Directly Under”.) The magnetic power frequency fields for a maximum continuous load directly under the power line for both existing and proposed power lines for the Lamoille Project are less than the guidelines set by the ICNIRP. This demonstrates that the projected maximum magnetic power frequency fields for the Lamoille Project are well below the health based ICNIRP guideline.

The projected magnetic frequency fields at the edge of the right of way and in the right of way are less than the ICNIRP guideline of 833 mG and the IEEE guideline of 9,040 mG for public exposure, respectively.

The existing and projected electric power frequency field directly under the power lines (0.32 to 0.39 kV/m and 0.72 to 2.54 kV/m, respectively) and at the ROW edge (0.23 to 0.27 kV/m and 0.61 to 1.91 kV/m, respectively) for the Lamoille Project are less than the ICNIRP guideline of 4.2 kV/m (refer to Appendix B Table 4 Columns “Existing Power Line”, “Proposed Power Line”). This demonstrates that the existing and projected maximum electric power frequency fields at the edge of the right of way and directly under the power lines for the Lamoille Project are well below the health based ICNIRP guideline.

The Vermont Department of Health:

1) Concludes that the data in the current body of literature is insufficient to establish a direct cause and effect relationship between EMF exposure and adverse health effects;

2) Concludes that the average and maximum electric and magnetic power frequency field strength for the proposed Lamoille Project does not appear to be a public health hazard based on a review of the literature and on calculations with existing and proposed electric current loads; and

3) Concludes that Vermont should continue to follow the policy of prudent avoidance outlined in the Vermont Twenty Year Electric Plan (1994) [8] in order to mitigate EMF exposures.

The Vermont Department of Health concludes that there are no compelling health concerns or reasons requiring modification to the Lamoille Project.

CURRENT SCIENTIFIC VIEW OF HUMAN HEALTH EFFECTS RELATED TO ELECTRIC AND MAGNETIC POWER FREQUENCY FIELDS

In this paper, electric and magnetic power frequency fields (“EMF”) refer to those fields produced by 60 hertz power lines. EMFs are produced by the earth, static electricity, lightning, and man-made devices. The static magnetic field around the earth is around 500 mG and is

produced by electric currents flowing in the earth's core. These static magnetic fields do not induce currents in stationary objects. However, currents may be induced in moving and rotating objects.

EMFs are also produced by high voltage transmission lines, distribution lines, wiring in buildings, and many commonly used appliances. Magnetic power frequency fields close to electrical appliances are often much stronger than those from other sources, including power lines. Exposures vary widely from clothes washers (up to 3 mG at 4 inches) to can openers (up to 4000 mG at 4 inches) [6].

Currently, there are no federal standards for occupational and residential exposure to EMF, nor standards or guidelines limiting EMF fields for appliance manufacturers at this time. The International Commission on Non-Ionizing Radiation Protection (ICNIRP) established guidelines for exposure of the public to magnetic and electric power frequency fields of 833 milligauss (mG) and 4.2 kilovolts per meter (kV/m), respectively [1]. The Institute of Electrical and Electronics Engineers' (IEEE) magnetic power frequency field guideline for exposure to the public is 9,040 mG and 5 kV/m for the electric power frequency field [2]. Florida has established guidelines for power lines less than 230 kV of 150 mG and 2.0 kV at the edge of the right-of-way when the power line is operating at its highest continuous current rating. The Florida guidelines are designed so that the maximum electric and magnetic power frequency fields will not exceed those fields produced by power lines now in operation. Their guidelines are not based on health effects. Germany (1997) adopted a national rule on EMF exposure for the general public limiting the electric power frequency field to 5 kV/m and the magnetic power frequency field to 1000 mG. These fields are unlikely to be encountered in daily life. Typical magnetic power frequency fields in the home average 0.6 mG [5] and range from 0.1 to 4 mG [30] over a period of a day. Average electric power frequency fields in the home range from 0 to 0.01 kV/m [7].

The relationship between EMF and health effects has been studied extensively since the late 1970's when there appeared to be a weak association between increased rates of childhood leukemia and proximity to transmission lines [9].

Current research is qualitatively superior to those early studies, though a uniform exposure metric has not been determined because there is no biological data that can be attributed to a specific measure of the magnetic power frequency field (e.g., time-averaged mG, cumulative mG, peak mG, time spent in a field above a certain strength).

The criteria scientists use to evaluate laboratory and epidemiologic studies of EMF and health effects are [5, 9]:

- 1) How strong is the association between EMF and a health effect? A strong association is defined as one with a relative risk (RR) of equal to or greater than 5 (e.g. smoking RR = 10 to 30). A relative risk of less than 3 is a weak association. An RR of less than 1.5 is essentially meaningless unless it is supported by other data. The RR for most electric and magnetic power frequency fields is less than 2, and is therefore classified as a weak association (the RR's have not increased as the quality of the studies has increased).
- 2) How consistent are the studies of associations between exposure to EMF and a health effect? Studies show decreases, no increases and some increases in the incidence of some types of cancers and some types of exposure metrics. Many studies are internally inconsistent (e.g. there is a positive association with calculated retrospective fields and negative association with measured EMFs).
- 3) Is there a dose response relationship between EMF and health effects? There are no published studies indicating a dose relationship between measured EMFs and cancer rates. The lack of a clear relationship between an exposure metric and increased health effect incidence is a major reason scientists are skeptical about the significance of much of the EMF epidemiology. Meta-analyses (combination of many epidemiological studies to attempt to calculate a summary risk estimate) have shown that there is a lack of adequate exposure information and clear dose response patterns to conclusively state that EMF causes cancer.
- 4) Is there laboratory evidence of an association between EMF and health effects? There is little evidence of the effect of EMF on cells, tissues or animals that point toward their being a cause of cancer. Existing laboratory studies have not yet been

able to establish a biological mechanism for how EMF may cause cancer. There is evidence that normal daily exposure to EMF is not carcinogenic.

- 5) Are there plausible biological mechanisms suggesting an association between exposure to EMF and health effects? Laboratory studies do not suggest an association between EMF and cancer. However, biological effects have been observed and reproduced in experiments using very high magnetic power frequency fields above 5,000 mG. Convincing evidence for EMF causing health effects is only available for magnetic field densities greater than approximately 1,000 mG [10].

Validation of studies of positive associations between EMF and health effects suffer from: 1) no attempt to replicate single positive studies; 2) lack of publication of studies; 3) replication of a positive study failed; 4) variation in exposure metrics and the lack of adequate detail to make an attempt at replication impossible to reproduce; and 5) the use of a wide variety of biological systems, endpoints, and exposure conditions [9].

The energy of the electric and magnetic power frequency fields from high voltage power lines (60 Hz) is insufficient to damage DNA (genetic material) in cells directly and to cause thermal effects in biological systems [4, 9]. Electrical currents generated in the human body by changes in a electric and magnetic power frequency field of less than 1 kV/m or 500 mG (AC current in the power lines) are much smaller than those produced naturally by the brain, nerves and heart [5, 9]. Electric power frequency fields may produce biological effects without damaging DNA by exerting forces on charged and uncharged molecules or cellular structures, however, the field strength applied to the biological system in order to produce these effects generally far exceeds those in typical environmental exposure conditions [9]. Magnetic power frequency fields can exert forces on cellular structures, but since biological materials are mostly nonmagnetic these forces are usually very weak [9].

Most evidence suggests that there is no consistent evidence that EMFs are genotoxins (agents capable of initiating damage to DNA), nor epigenetic agents (agents contributing to development of cancer or promoters) [9]. There are several factors that result in false associations between EMF and health effects in some studies: 1) inappropriate controls (e.g.

laboratory studies were not performed under controlled conditions, difficulty of obtaining a control group identical to the exposed group); 2) inadequate dose assessment (e.g. reliability of the exposure information and what exposure metric of the EMF is involved); 3) confounders (e.g. traffic density and socioeconomic class); 4) publication bias (e.g. unrepresentative subsets of the actual study are reported, positive studies are more likely to be published); and 5) multiple comparison artifacts (e.g. studies using multiple exposure metrics and/or multiple health effect endpoints) [9]. Studies that have initially shown a positive association between EMF and health effects have not been successfully replicated in many cases.

Electric power frequency fields are sensed as mild shocks when touching a conducting material while standing directly under a high voltage power line. Electric power frequency fields, from high voltage power lines, are easily shielded by conducting objects (houses, trees, and human skin) [9]. Electric power frequency fields do not change with increasing current through the power lines. Many studies show that the electric power frequency fields around power lines do not affect human health [9].

The easiest method of reducing exposure to either the magnetic or electric power frequency field is by increasing your distance away from the power lines. The magnetic and electric power frequency field strength decreases as the inverse of the square of the distance. In other words, if a person moves from 2 feet to 4 feet away from a source then the field strength decreases by a factor of 4. Spending less time near the source also will decrease the cumulative exposure.

However, exposure to EMFs has not been proven to be absolutely safe due to the small proportion of studies that have shown a small increase in health effects. This increase in health effects may be restricted to very small subgroups and for those occupationally exposed to high EMF fields.

Some laboratory studies suggest that there may be “windows” for health effects, which may be observed at some frequencies and intensities but not at others. Also, it is not known if continuous exposure to or repeated entrance and exiting a given field intensity causes a

biological effect. Many laboratory studies (*in vivo* and *in vitro*) test at magnetic power frequency field strengths far above that which is normally encountered in the daily environment (e.g. up to 20,000 mG [9]). Because of all this uncertainty, it is difficult to determine a “safe” distance from any magnetic power frequency field source or a “safe” exposure. At this point in time only comparisons can be made from one set of field conditions to another. For example, the average magnetic power frequency field common in households and offices (primarily from the wiring and outside power lines) is 0.6 mG [5] varying from 0.1 to 4 mG [6]. Average electric power frequency fields in the home range from 0 to 0.01 kV/m [7].

There are no known definitive studies indicating that EMFs cause adverse health effects. However, with advances in science and technology, it could be possible that EMFs may in the future be shown to cause health concerns. Related issues that are brought up are: 1) what type of scientific studies should be done, and 2) what priority should these studies should be given.

Based on the current level of science and technology for electric and magnetic power frequency fields projected from the Lamoille Project, adverse health effects are not an issue. A new project with higher voltage power lines, the addition of power lines in the same corridor, or new technologies would require the reanalysis of the health effects from the power lines.

Excerpts from a number of scientific reviews of the literature and research on electrical and magnetic power frequency fields from the national, state and international levels, upon which we relied in the development of this position paper regarding electrical and magnetic power frequency fields and the Lamoille Project, are listed below. Most scientific reviews conclude that there is insufficient evidence to prove that EMFs from high voltage power lines cause human health effects, though some show a very weak association.

National Agencies

Electric Power Research Institute (EPRI) (2005)[47]:

“Although epidemiologic studies show that magnetic field exposure at or above 3 to 4 milligauss may increase the risk of childhood leukemia, it cannot be concluded that a cause-and-effect relationship

exists. The reported association between magnetic fields and childhood leukemia is weak (children with exposure above 3 milligauss might have roughly double the risk of unexposed children). For such weak epidemiologic associations, supporting data from laboratory studies are usually critical for establishing a causal link. For example, exposures or agents that are known to cause cancers in humans (such as ionizing radiation and benzene) also cause cancers in laboratory rodents. Such laboratory evidence should also be supported by an understanding of the mechanisms by which the exposures or agents interact with biological tissue. For magnetic fields, lifetime studies of rodents almost all report no adverse effects, and scientists have not identified a mechanism by which the low-level fields found in homes can possibly interact with tissue. In the absence of supporting laboratory and mechanistic evidence, scientists are investigating the possibility that the epidemiologic results have been generated by inadvertent errors in study design or that magnetic fields occur along with another exposure that could plausibly cause leukemia.

American Cancer Society (ACS), What are the Risk Factors for Acute Myeloid Leukemia (AML)? (2005)[45]:

“There is some question about electromagnetic field (EMF) exposure (such as that occurring near very high-voltage power lines) as a potential risk factor for developing leukemia. Most studies published so far suggest either no increased risk or a very slightly increased risk. Clearly, most cases of leukemia are not related to EMF exposure.”

American Cancer Society (ACS), Unproven Risks (2002)[46]:

“Non-ionizing radiation. Electromagnetic radiation at frequencies below ionizing and ultraviolet levels has not been proven to cause cancer. Some studies suggest an association with cancer, but most of the no2-extensive research in this area does not.”

American Cancer Society (ACS) (2002) [11]:

“There is conflicting evidence about electromagnetic field (EMF) exposure (such as that occurring near very high-voltage power lines) as a potential risk factor for developing leukemia. The NCI [National Cancer Institute] has several large studies going on now to look into this question. Most studies published so far suggest either no increased risk or a very slightly increase risk. Clearly, most cases of leukemia are not related to EMF exposure.”

Institute of Electrical and Electronics Engineers (IEEE), Committee on Man and Radiation (COMAR) (2002) [2]:

“Protection is to be afforded to individuals in the general population by limiting maximum permissible exposure (MPD) to magnetic field levels of 9,040 mG at 60-Hz power-line frequencies.”

American Conference of Governmental Industrial Hygienists (ACGIH) (2002)[12]:

“It is recommended that lacking specific information on electromagnetic interference from the manufacturer, the exposure of persons wearing cardiac pacemakers or similar medical electronic devices be maintained at or below 1,000 mG at power-line frequencies (60 Hz).”

Institute of Electrical and Electronics Engineers (IEEE), Committee on Man and Radiation (COMAR) (2000) [13]:

“After examination of relevant research reports published during the last ten years, COMAR [Committee on Man and Radiation] concludes that it is highly unlikely that health problems can be associated with average 24-hour field exposure to power frequency magnetic fields of less than 1 microT (10 mG).”

National Institute of Environmental Health Sciences (NIEHS) (1999)[10] :

“The scientific evidence suggesting that ELF-EMF [Extremely Low Frequency Electric and Magnetic Fields] exposures pose any health risk is weak. The strongest evidence for health effects comes from associations observed in human populations with two forms of cancer: childhood leukemia and chronic lymphocytic leukemia in occupationally exposed adults. While the support from individual studies is weak, the epidemiological studies demonstrate, for some methods of measuring exposure, a fairly consistent pattern of a small, increased risk with increasing exposure that is somewhat weaker for chronic lymphocytic leukemia than for childhood leukemia. In contrast, the mechanistic studies and the animal toxicology literature fail to demonstrate any consistent pattern across studies although sporadic findings of biological effects (including increased cancers in animals) have been reported. No indication of increased leukemias in experimental animals has been observed....

The NIEHS concludes that ELF-EMF exposure cannot be recognized as entirely safe because of weak scientific evidence that exposure may pose a leukemia hazard. In our opinion, this finding is insufficient to warrant aggressive regulatory concern. However, because virtually everyone in the United States uses electricity and therefore is routinely exposed to ELF-EMF, passive regulatory action is warranted such as a continued emphasis on educating both the public and the regulated community on

means aimed at reducing exposure. The NIEHS does not believe that other cancers or non-cancer health outcomes provide sufficient evidence of a risk to currently warrant concern.”

“The association between exposure to magnetic fields and a variety of other cancers has also been considered in occupational settings. Included are brain cancers, breast cancers (in both males and females), testicular cancers, cancers in offspring of workers, lymphoma, multiple myeloma, melanoma, non-Hodgkin’s lymphoma, thyroid cancers and many other. Some evidence exists for an association between brain cancers and exposure to ELF-EMF and between female breast cancers and ELF-EMF exposure; however, the studies evaluating these associations are inconsistent and have limits to their interpretation making them inadequate for supporting or refuting an effect. In the remaining cases, the evidence supporting an association is negative or too weak to warrant concern....

Limited data are available on risks of male and female breast cancer associated with residential exposure to ELF-EMF. A small, non-significant association between use of electric blankets and the risk for breast cancer was observed in one, large U.S. study but not in another. Both found no evidence for an association with duration of exposure. Three studies, using exposure measured by calculated fields, identified an association between exposure to magnetic fields and the risk of breast cancer. These same scientists also looked at exposure to ELF-EMF and cancers of the central nervous system (such as brain cancers); no associations were found.”

“The association between occupational exposure to ELF-EMF (Extremely Low Frequency – Electromagnetic Fields) and Alzheimer’s disease was considered in five studies. All five studies showed increases in one or more exposure groups with four studies showing statistically significant increase and one showing non-statistically significant increases. All of these studies suffer from design limitations that make it inappropriate to use them for addressing a causal association between ELF-EMF exposure and Alzheimer’s disease. Two of these are based on diagnoses from death certificates (Alzheimer’s disease is not consistently noted on death certificates). Two studies used different groups of cases and controls; some of the control groups included persons with other types of dementia, and proxy information was used to define the exposure of cases. The one remaining study was evaluated using data for twins and also suffered many limitations. These data are inadequate for interpreting the possibility of an association.

The association between exposure to magnetic fields and amyotrophic lateral sclerosis was assessed in three studies. One study showed an increase risk in the highest exposure group and the other two studies were negative. Adequate adjustment could not be made for known risk factors (electric shocks or a family history of amyotrophic lateral sclerosis) making these studies difficult to interpret...”

“Two occupational studies assessed possible adverse cardiovascular outcomes that may result from exposure to magnetic fields. In the first study, a significant decrease in risk using a broadly defined

cardiovascular grouping was observed. In the second, data from five utilities were examined. This study was motivated *a priori* by a biological hypothesis based on the results of human clinical studies on heart rate variability for increase numbers of deaths due to arrhythmia and acute myocardial infarct. Significant exposure-dependent associations were reported. Lacking additional epidemiological studies to collaborate these results, these data are inconclusive regarding an association between cardiovascular disease and exposure to ELF-EMF.”

“The NIEHS suggests that the level and strength of evidence supporting ELF-EMF exposure as a human health hazard are insufficient to warrant aggressive regulatory actions; thus, we do not recommend actions such as stringent standards on electric appliances and a national program to bury all transmission and distribution lines. Instead, the evidence suggests passive measures such as a continued emphasis on educating both the public and the regulated community on means aimed at reducing exposures. NIEHS suggests that the power industry continue its current practice of siting power lines to reduce exposure and continue to explore ways to reduce the creation of magnetic fields around transmission and distribution lines without creating new hazards. We also encourage technologies that lower exposure from neighborhood distribution lines provided that they do not increase other risks, such as those from accidental electrocution or fire....

In summary, the NIEHS believes that there is weak evidence for possible health effects from ELF-EMF exposures, and until stronger evidence changes this opinion, inexpensive and safe reduction in exposure should be encouraged.”

U. S. National Academy of Science (NAS) (1996) [14]:

“Based on a comprehensive evaluation of published studies relating to the effects of power-frequency electric and magnetic fields on cells, tissues, and organisms (including humans), the conclusion of the committee is that the current body of evidence does not show that exposure to these fields presents a human-health hazard. Specifically, no conclusive and consistent evidence shows that exposure to residential electric and magnetic fields produce cancer, adverse neurobehavioral effects, or reproductive and developmental effects.”

Oak Ridge Associated Universities (ORAU)

Panel for the Committee on Interagency Radiation Research and Policy Coordination (CIRRPC)
Health Effects of Low-Frequency Electric and Magnetic Fields (1992) [15]:

“This review indicates that there is no convincing evidence in the published literature to support the contention that exposures to extremely low-frequency electric and magnetic fields (ELF-EMF)

generated by sources such as household appliances, video display terminals, and local power lines are demonstrable health hazards. Epidemiologic findings of an association between electric and magnetic fields and childhood leukemia or other childhood or adult cancers are inconsistent and inconclusive. No plausible biological mechanism is presented that would explain causality. Neither is there conclusive evidence that these fields initiate cancer, promote cancer or influence tumor progression. Likewise, there is no convincing evidence to support suggestions that electric and magnetic fields result in birth defects or other reproductive problems. Furthermore, any neurobehavioral effects are likely to be temporary and do not appear to have health consequences.”

U.S. Environmental Protection Agency (EPA)

Evaluation of the Potential Carcinogenicity of Electromagnetic Fields, External Review Draft, October 1990 [16]:

“In evaluating the potential for carcinogenicity of chemical agents, the U.S. EPA has developed an approach that attempts to integrate all of the available information into a summary classification of the weight of evidence that the agent is carcinogenic in humans. At this time, such a characterization regarding the link between cancer and exposure to EMF fields is not appropriate because the basic nature of the interaction between EM fields and biological processes leading to cancer is not understood. ... With our current understanding, we can identify 60 Hz magnetic fields from power lines and perhaps other sources in the home as a possible, but not proven, cause of cancer in humans.”

International Agencies

U.K. National Radiation Protection Board (NRPB) (2004) [48]:

“Power frequency fields – In the context of possible adverse health effects from EMFs, the conclusions of published expert scientific reviews have identified only one reasonably consistent epidemiological finding of an adverse health outcome associated with exposure to EMFs at levels lower than exposure guidelines: that is an apparent increased risk of childhood leukaemia with time-weighted exposure to power frequency magnetic fields above 0.4 μ T (4 mG). It is the view of NRPB that the epidemiological evidence is currently not strong enough to justify a firm conclusion that such fields cause leukaemia in children... The view of NRPB is that it is important to consider the possible need for further precautionary measures in respect of exposure of children to power frequency magnetic fields.”

U.K. National Radiation Protection Board (NRPB) (2004) [49]:

“In the view of NRPB, the epidemiological evidence that time-weighted average exposure to power frequency magnetic fields above 0.4 μ T (4 mG) is associated with a small absolute raised risk of leukaemia in children is, at present, an observation for which there is no sound scientific explanation. There is no clear evidence of a carcinogenic effect of ELF EMFs in adults and no plausible biological explanation of the association can be obtained from experiments with animals or from cellular and molecular studies. Alternative explanations for this epidemiological association are possible: for example, potential bias in the selection of control children with whom leukaemia cases were compared in some studies and chance variations resulting from small numbers of individuals affected. Thus any judgements developed on the assumption that the association is causal would be subject to a very high level of uncertainty...

NRPB concludes that the results of epidemiological studies, taken individually or as collectively reviewed by expert groups, cannot currently be used as a basis for restrictions on exposure to EMFs...

In addition, a number of studies suggest that ELF EMFs, particularly magnetic fields in excess of about 100 μ T (1,000 mG), may induce a variety of subtle responses in biological systems, as well as those attributable to the effects of either surface charge or the induced electric field. However, the pattern of reported responses is diffuse and inconsistent. Furthermore, many tend to be small in magnitude and often fail to be replicated. Overall, none is considered sufficient to provide a coherent framework on which to base restrictions for human exposures...

It is concluded that currently the results of these studies on EMFs and health, taken individually or as collectively reviewed by expert groups, are insufficient either to make a conclusive judgement on causality or to quantify appropriate exposure restriction. This conclusion is in accord with the manner in which other expert bodies – for example, ICNIRP (1998) – have developed EMF exposure guidelines.

However, such studies taken together with people's concerns provide a basis of considering the possible need for further precautionary measures in addition to the application of quantitative restrictions on exposure to EMFs...

There remain concerns about possible effects of exposure of children to power frequency magnetic fields. The view of NRPB is that it is important to consider the possible need for further precautionary measures in respect of exposure of children to power frequency magnetic fields...

The government should consider the need for further precautionary measures in respect of exposure of people to EMFs. In doing so, it should note that the overall evidence for adverse effects of EMFs on health at levels of exposure normally experienced by the general public is weak. The least weak evidence is for the exposure of children to power frequency magnetic fields and childhood leukaemia.”

International Agency for Research on Cancer (IARC) (2002) [17]:

“The association between childhood leukaemia and high levels of magnetic fields is unlikely to be due to chance, but it may be affected by bias. In particular, selection bias may account for part of the association.”

“...there is limited evidence in humans for the carcinogenicity of extremely low-frequency magnetic fields in relation to childhood leukaemia. There is inadequate evidence in humans for the carcinogenicity of extremely low-frequency magnetic fields in relation to all other cancers.”

International Agency for Research on Cancer (IARC) (2001) [18]:

“In June 2001, an expert scientific working group of IARC reviewed studies related to the carcinogenicity of static and ELF electric and magnetic fields. Using the standard IARC classification that weighs human, animal and laboratory evidence, ELF magnetic fields were classified as possibly carcinogenic to humans based on epidemiological studies of childhood leukaemia. Evidence for all other cancers in children and adults, as well as other types of exposures (i.e. static fields and ELF electric fields) was considered not classifiable either due to insufficient or inconsistent scientific information.

‘Possibly carcinogenic to humans’ is a classification used to denote an agent for which there is limited evidence of carcinogenicity in humans and less than sufficient evidence for carcinogenicity in experimental animals.

This classification is the weakest of three categories (‘is carcinogenic to humans’, ‘probably carcinogenic to humans’ and ‘possibly carcinogenic to humans’) used by IARC to classify potential carcinogens based on published scientific evidence.”

“Group 2B: The agent (mixture) is possibly carcinogenic to humans.

The exposure circumstance entails exposures that are possibly carcinogenic to humans.

This category is used for agents, mixtures and exposure circumstances for which there is *limited evidence* of carcinogenicity in humans and less than *sufficient evidence* of carcinogenicity in experimental animals. It may also be used when there is *inadequate evidence* of carcinogenicity in humans but there is *sufficient evidence* of carcinogenicity in experimental animals. In some instances, an agent, mixture or exposure circumstance for which there is *inadequate evidence* of carcinogenicity in humans but *limited evidence* of carcinogenicity in experimental animals together with supporting evidence from other relevant data may be placed in this group.”

*Please note the IARC lists 236 different materials classified as “possible carcinogens”. Also included are coffee, pickled vegetables, gasoline engine exhaust, welding fumes, and chloroform.

World Health Organization (WHO Fact Sheet 263, 2001) [19]:

“It is especially difficult to suggest protective measures for ELF fields because we do not know what field characteristic might be involved in the development of childhood leukaemia and therefore need to be reduced, or even if it is the ELF magnetic fields that are responsible for this effect. One approach is to have voluntary policies that aim to cost-effectively reduce exposure to ELF fields.”

International Commission on Non-Ionizing Radiation Protection (ICNIRP) (2001) [20]:

“In the absence of evidence from cellular or animal studies, and given the methodological uncertainties and in many cases inconsistencies of the existing epidemiologic literature, there is no chronic disease outcome for which an etiological relation to EMF exposure can be regarded as established.”

U.K. National Radiation Protection Board (NRPB) (2001) [21]:

“Laboratory experiments have provided no good evidence that extremely low frequency electromagnetic fields are capable of producing cancer, nor do human epidemiological studies suggest that they cause cancer in general. There is, however, some epidemiologic evidence that prolonged exposure to higher levels of power frequency magnetic fields is associated with a small risk of leukaemia in children. ... In the absence of clear evidence of a carcinogenic effect in adults, or of plausible explanation from experiments on animals or isolated cells, the epidemiological evidence is currently not strong enough to justify a firm conclusion that such fields cause leukaemia in children. Unless however, further research indicates that the finding is due to chance or some currently unrecognized artifact, the possibility remains that intense and prolonged exposures to magnetic fields can increase the risk of leukaemia in children.”

World Health Organization (WHO Fact Sheet 205, 1998) [22]:

“Consultation with local authorities and the public in siting new power lines: Obviously power lines must be sited to provide power to consumers. Despite the fact that ELF field levels around transmission and distribution lines are not considered a health risk, siting decisions are often required to take into account aesthetics and public sensibilities. Open communication and discussion between the electric power utility and the public during the planning stages can help create public understanding and greater acceptance of a new facility.”

State Agencies

Minnesota Department of Health (2002) [4]:

“The Minnesota Department of Health concludes that the current body of evidence is insufficient to establish a cause and effect relationship between EMF and adverse health effects. However, as with many other environmental health issues, the possibility of a health risk from EMF cannot be dismissed. Construction of new generation and transmission facilities to meet increasing electrical needs in the State is likely to increase public exposure to EMF. Based on these considerations, the Work Group considers it prudent public health policy to take a prudent avoidance approach to mitigating EMF exposures.”

Florida Department of Environmental Protection (2001) [23]:

“We seem to be approaching a time when some aspects of EMF exposure may be deemed a slight risk, but we are still lacking knowledge of EMF impact mechanisms and adequate scientific proof to allow a valid estimate of risk to the public and the knowledge to set a regulatory standard to manage the risk.”

California Department of Health Services (draft 2001) [24]:

“To one degree or another all three of the DHS scientists are inclined to believe that EMFs can cause some degree of increased risk of childhood leukemia, adult brain cancer, Lou Gehrig’s Disease, and miscarriage. They strongly believe that EMFs do not increase the risk of birth defects, or low birth weight. They strongly believe that EMFs are not universal carcinogens, since there are a number of cancer types that are not associated with EMF exposure. To one degree or another they are inclined to believe that EMFs do not cause an increased risk of breast cancer heart disease, Alzheimer’s Disease, depression, or symptoms attributed by some to a sensitivity to EMFs. However, all three scientists had judgments that were close to the dividing line between believing and not believing that EMFs cause some degree of increased risk of suicide, or for adult leukemia, two of the scientists are close to the dividing line between believing or not believing and one was prone to believe that EMFs cause some degree of increased risk.”

Virginia Department of Health (2000) [25]:

“Based on the review and analysis of the exhaustive literature review and other research projects completed under the EMF-RAPID program, the Virginia Department of Health is of the opinion that there is no conclusive and convincing evidence that exposure to extremely low frequency EMF emanated from

nearby high voltage transmission lines is causally associated with an increased incidence of cancer or other detrimental health effects in humans.”

Connecticut Department of Environmental Protection and Department of Health Services (1994) [26]:

“No definitive cause and effect relationship between exposure to EMF and an increase in health risk has been established.”

Maryland Department of Natural Resources (1994) [27]:

“It is impossible to predict effects (or lack of effects) with any certainty, and it is not clear which biological effects observed in cellular or animal studies (if any) could have significant human health implications. ... There is no definitive indication that EMF exposure does or does not cause adverse health effects.”

Oregon Department of Energy (1993) [28]:

“Some early epidemiological studies have suggested an association between EMF exposure and increased risk for diseases such as leukemia in children, brain cancer, male breast cancer, lymphoma, miscarriages and birth defects. However, research to date has not shown that EMF exposure causes these diseases.”

Texas Public Utility Commission

Health Effects of Exposure to Power-Frequency Electric and Magnetic Fields (1992) [29]:

“The Committee believes that, based on its evaluation of the existing EMF research, the evidence at this time is insufficient to conclude that exposure to EMF from electric power transmission lines poses an imminent or significant public health risk. ... The Committee concludes that at present there is insufficient evidence regarding human health effects of EMF to provide the basis for a health-based standard.”

Illinois Department of Public Health and Environmental Protection Agency

Possible Health Effects of Extremely Low Frequency Electric and Magnetic Field Exposure: A Review (1992) [30]:

“Whether these observed ELF bioeffects cause adverse health effects in humans and animals is not yet clear. No scientific consensus has been reached on this issue. Without sufficient information,

health risks from exposure to these fields cannot be properly determined. ... Because some studies have identified positive associations between ELF field exposure and certain adverse health effects, while other studies have not, the data obtained to date are far from conclusive.”

Vermont Public Service Board (Docket No. 6860, January 28, 2005)[33]

A Certificate of Public Good issued by the Vermont PSB for the Northwest Vermont Reliability Project states:

“The Board finds that the electric and magnetic fields (“EMF”) that will result from the proposed Project are very unlikely to have an undue adverse effect on public health. It is not possible to state unequivocally that there will be no adverse health effects. Some epidemiological studies have found a weak correlation between EMF and childhood leukemia, despite the fact that no mechanism of causation has been found....Based upon the recommendations of the NIEHS, the Board finds that the policy of prudent avoidance, which we adopt, does not require a generic policy of placing transmission lines underground to avoid EMF exposure....We will not require VELCO to place underground any portion of the project based upon the health effects of EMF....In addition, we note that the conclusions of VELCO’s EMF witness and the Vermont Department of Health appear to be consistent with the conclusions of the major health agencies who have rigorously studied this issue.”

GUIDELINES FROM SAFETY ORGANIZATIONS

International Commission on Non-Ionizing Radiation Protection (ICNIRP) (60 Hz General Public, 1998) [1]:

Magnetic Power Frequency Field:	833 mG
Electric Power Frequency Field:	4.2 kV/m

“Induction of cancer from long-term EMF exposure was not considered to be established, and so these guidelines are based on short-term, immediate health effects such as stimulation of peripheral nerves and muscles, shocks and burns caused by touching conducting objects, and elevated tissue temperatures resulting from absorption of energy during exposure to EMF.”

Institute of Electrical and Electronics Engineers (IEEE) (Standard C95.6 General Public) [2]:

Magnetic Power Frequency Field:	9040 mG
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Electric Power Frequency Field:

5.0 kV/m

World Health Organization (WHO Fact Sheet N182, 1998) [31]:

“Safety Standards: In order to ensure that human exposure to EMF should not have adverse health effects, that man-made EMF generating devices are safe and their use does not electrically interfere with other devices, various international guidelines and standards are adopted. Such standards are developed following reviews of all the scientific literature by groups of scientists who look for evidence of consistently reproduced effects with adverse health consequences. These groups then recommend guidelines for standards for action by the appropriate national and international bodies. A non-governmental organization, formally recognised by WHO in the field of NIR [non-ionizing radiation] protection, is the International Commission on Non-Ionizing Radiation Protection (ICNIRP). ICNIRP has established international guidelines on human exposure limits for all electromagnetic fields, including ultraviolet (UV) radiation, visible light and infrared radiation, as well as RF fields and microwaves... Even high intensity NIR cannot cause ionization in the biological system. NIR, however, have been shown to produce other biological effects, for instance, by heating, altering normal chemical reactions or inducing electrical currents in tissues.”

STATE GUIDELINES

Please note that the bolded text in this section was added for ease of reference.

Florida 62-814.450 (2001) [23]:

- “(3) New transmission lines and substations.
- (a) The **maximum electric field at the edge of the transmission line ROW** or at the property boundary of a new substation shall not exceed **2.00 kV/m**.
- (b) The **maximum electric field on the ROW of a 230 kV or smaller** transmission line **shall not exceed 8 kV/m**.
- (c) The maximum electric field on the ROW of a 500 kV transmission line shall not exceed 10 kV/m.
- (d) The **maximum magnetic field at the edge of a 230 kV or smaller** transmission line ROW or at the property boundary of a new substation serving such lines **shall not exceed 150 milligauss**.

(e) The maximum magnetic field at the edge of the transmission line ROW for a 500 kV line or at the property boundary of a new substation serving a 500 kV line shall not exceed 200 milligauss, except for double circuit 500 kV lines to be constructed on ROWs existing on March 21, 1989, as identified below where the limit will be 250 milliGauss.”

California (1999) [32]:

“The California Department of Education enacted regulations that require minimum distances between a new school and the edge of a transmission “right-of-way,” or the area immediately surrounding lines that utility companies need to access the lines for maintenance and repairs. The setback distances are 100 feet for 50-133 kV lines, 150 feet for 220-230 kV lines, and 350 feet for 500-550 kV lines. These distances were not based on specific biological evidence, but on the known fact that the strength of electric fields from powerlines drops to near background levels at the specified distances, given that no major sources are present.”

WILL THE PROJECTED ELECTRIC AND MAGNETIC POWER FREQUENCY FIELDS INCREASE, DECREASE OR STAY THE SAME WITH THE PROPOSED LAMOILLE PROJECT?

The VDH performed many calculations using an EXCEL format of the Bonneville Power Authority program provided by VELCO to derive existing and projected estimates of the electric and magnetic power frequency fields. Data was provided by VELCO and is listed in Appendix A. Data required for the calculations include: 1) continuous load ratings, 2) distance of the power line from the center of the ROW, 3) sag height of the power line, 4) number of conductors, 5) diameter of the conductor, 6) bundle diameter, 7) line to ground voltage, 8) phase angle, 9) existing and projected average loading, and 10) existing and projected maximum loading. The calculations use the maximum power line kV, the maximum sag (minimum allowed height above the ground) and maximum line to ground voltage. The transmission line is modeled as a horizontal line at the estimated sag height.

The ROW of the Proposed Lamoille Project ranges from 100 feet to 175 feet. Calculations were performed using a conservative assumption of a 40-foot ROW based on the distance of existing homes from the proposed power line.

Cross-sections for each corridor were taken from Ryan C. Johnson's Exhibits RCJ-18, RCJ-19, RCJ-20, RCJ-21, RCJ-22, and RCJ-23.

Using these parameters and assumptions the estimated existing and projected results are maximum possible values for the electric and magnetic power frequency fields. The results of these calculations are very conservative estimates and are not "real" or measured fields.

Comparison of the electric and magnetic power frequency fields calculated for this report indicate different values than those reported in the Direct Testimony of Peter A. Valberg (12/6/2004) because data provided from VELCO for this report was based on the absolute maximum sag assuming NESC minimum clearance heights, average loading (50% of winter peak load), and maximum continuous loading of the power lines. As a result, the estimated electric and magnetic power frequency fields using these parameters are more likely to represent the highest expected fields along each corridor, so that the VDH can assure that the highest expected fields will not exceed the ICNIRP guidelines.

ELECTRIC AND MAGNETIC POWER FREQUENCY FIELDS AT AVERAGE LOADING AT THE EDGE OF THE RIGHT OF WAY (APPENDIX B, TABLES 1 & 4)

The magnetic power frequency field along the RCJ-18 corridor is projected to increase² at the edge of the ROW for average loading from 17 mG in 2006 to 21 mG in 2015. The electric power frequency field is projected to be 1.91 kV/m in 2006 and will not change as the current changes or with time

The magnetic power frequency field along the RCJ-19 corridor is projected to increase at the edge of the ROW for average loading from 3.6 mG in 2006 to 14 mG in 2015. The electric power frequency field is projected to increase from 0.23 kV/m to 1.33 kV/m in 2006 and will not change as the current changes or with time.

The magnetic power frequency field along the RCJ-20 corridor is projected to increase at the edge of the ROW for average loading from 3.6 mG in 2006 to 20 mG in 2015. The electric power frequency field is projected to increase from 0.23 kV/m to 1.85 kV/m in 2006 and will not change as the current changes or with time.

The magnetic power frequency field along the RCJ-21 corridor is projected to increase at the edge of the ROW for average loading from 17 mG in 2006 to 20 mG in 2015. The electric power frequency field is projected to increase from 0.27 kV/m to 1.86 kV/m in 2006 and will not change as the current changes or with time.

The magnetic power frequency field along the RCJ-22 corridor is projected to decrease at the edge of the ROW for average loading from 17 mG in 2006 to 13 mG in 2015. The electric power frequency field is projected to increase from 0.27 kV/m to 0.61 kV/m in 2006 and will not change as the current changes or with time.

² When the Proposed Reroute corridor is a new transmission corridor the concept of “increase” relates to the increase in electric or magnetic power frequency fields between the year of installation (2006) and 2015.

The magnetic power frequency field along the RCJ-23 corridor is projected to increase at the edge of the ROW for average loading from 4.4 mG in 2006 to 44 mG in 2015. The electric power frequency field is projected to increase from 0.27 kV/m to 1.80 kV/m in 2006 and will not change as the current changes or with time.

The magnetic power frequency field for average loading at the edge of the ROW is projected to increase with the Lamoille Project between 2006 and 2012. The projected magnetic power frequency field for average loading at the edge of the ROW ranges from 13 to 44 mG and the average is approximately 22 mG in 2015. The proposed replacement of the 34.5 kV power or addition of the 115 kV power line will allow more current to flow increasing the magnetic power frequency field. The projected magnetic power frequency fields at the edge of the ROW are approximately 6 and 30 times less than the Florida and ICNIRP guidelines, respectively, for public exposure. The projected electric power frequency fields at the edge of the ROW are approximately 1.2 and 3 times less than the Florida and ICNIRP guidelines, respectively.

CONCLUSION

The magnetic power frequency fields at the edge of the ROW for average loading with the Lamoille Project are projected to be on the order of 6 times less than the Florida guideline of 150 mG and 30 times less than the ICNIRP guideline of 833 mG for public exposure. The electric power frequency fields at the edge of the ROW for average loading with the Lamoille Project Proposed Reroutes are projected to be less than the Florida guideline of 2 kV/m, and 3 times less than the ICNIRP guideline of 4.2 kV/m. This demonstrates that the projected magnetic and electric power frequency fields for average loading for the Lamoille Project Proposed Reroutes are well below the health-based ICNIRP guidelines.

ELECTRIC & MAGNETIC POWER FREQUENCY FIELDS AT AVERAGE LOADING DIRECTLY UNDER THE POWER LINES (APPENDIX B, TABLES 2 & 4)

The magnetic power frequency field along the RCJ-18 corridor is projected to increase for average loading directly under the power lines from 17 mG in 2006 to 22 mG in 2015. The electric power frequency field is projected to be 2.05 kV/m in 2006 and will not change as the current changes or with time.

The magnetic power frequency field along the RCJ-19 corridor is projected to increase for average loading directly under the power lines from 9 mG in 2006 to 28 mG in 2015. The electric power frequency field is projected to increase from 0.32 kV/m to 1.58 kV/m in 2006 and will not change as the current changes or with time.

The magnetic power frequency field along the RCJ-20 corridor is projected to increase for average loading directly under the power lines from 9 mG in 2006 to 28 mG in 2015. The electric power frequency field is projected to increase from 0.32 kV/m to 2.18 kV/m in 2006 and will not change as the current changes or with time.

The magnetic power frequency field along the RCJ-21 corridor is projected to decrease for average loading directly under the power lines from 43 mG in 2006 to 28 mG in 2015. The electric power frequency field is projected to increase from 0.39 kV/m to 2.19 kV/m in 2006 and will not change as the current changes or with time.

The magnetic power frequency field along the RCJ-22 corridor is projected to decrease for average loading directly under the power lines from 43 mG in 2006 to 13 mG in 2015. The electric power frequency field is projected to increase from 0.39 kV/m to 0.72 kV/m in 2006 and will not change as the current changes or with time.

The magnetic power frequency field along the RCJ-23 corridor is projected to increase for average loading directly under the power lines from 11 mG in 2006 to 44 mG in 2015. The

electric power frequency field is projected to increase from 0.39 kV/m to 2.11 kV/m in 2006 and will not change as the current changes or with time.

The magnetic power frequency field for average loading directly under the power line is projected to increase with the Lamoille Project between 2006 and 2015. The projected magnetic power frequency field for average loading directly under the power ranges from 13 mG to 44 mG and the average is approximately 27 mG in 2015. The proposed replacement of the 34.5 kV power or addition of the 115 kV power line will allow more current to flow increasing the magnetic power frequency field. The projected magnetic power frequency fields directly under the power line are approximately 4 and 25 times less than the Florida and ICNIRP guidelines, respectively, for public exposure. The projected electric power frequency fields directly under the power line is 4 times less than the Florida guideline of 8 kV/m and 2 times less than the ICNIRP guideline of 4.2 kV/m.

CONCLUSION

The magnetic power frequency fields with the Lamoille Project for average loading directly under the power lines are projected to be on the order of 4 times less than the Florida guideline of 150 mG and 25 times less than the ICNIRP guideline of 833 mG for public exposure. The electric power frequency fields directly under the power line for average loading with the Lamoille Project Proposed Reroutes are projected to be approximately 4 times less than the Florida guideline of 8 kV/m, and 2 times less than the ICNIRP guideline of 4.2 kV/m. This demonstrates that the projected magnetic and electric power frequency fields for average loading directly under the power line for the Lamoille Project are well below the health-based ICNIRP guidelines.

MAGNETIC POWER FREQUENCY FIELDS AT MAXIMUM CONTINUOUS LOADING AT THE EDGE OF THE ROW (APPENDIX B, TABLE 3)

The maximum projected magnetic power frequency field at the edge of the ROW for maximum continuous loading for the Lamoille Project are as follows: RCJ-18 corridor is 417 mG in 2006; RCJ-19 corridor increases from 33 mG to 177 mG; RCJ-20 corridor increases from 33 mG to 259 mG; RCJ-21 corridor increases from 57 mG to 251 mG; RCJ-22 corridor increases from 57 mG to 169 mG; and RCJ-23 corridor increases from 57 mG to 392 mG.

CONCLUSION

The magnetic power frequency fields at the edge of the ROW with the Lamoille Project for maximum continuous loading are projected to be approximately 3 times less than the ICNIRP guideline of 833 mG, and 25 times less than the IEEE guideline of 9,040 mG for public exposure. This demonstrates that the projected maximum magnetic power frequency fields at the edge of the ROW for the Lamoille Project are well below the health-based ICNIRP guideline.

MAGNETIC POWER FREQUENCY FIELDS AT MAXIMUM CONTINUOUS LOADING DIRECTLY UNDER THE POWER LINE (APPENDIX D, TABLE 3)

The maximum projected magnetic power frequency field directly under the power line for maximum continuous loading for the Lamoille Project are as follows: RCJ-18 corridor is 417 mG in 2006; RCJ-19 corridor increases from 80 mG to 358 mG; RCJ-20 corridor increases from 80 mG to 358 mG; RCJ-21 corridor increases from 140 mG to 361 mG; RCJ-22 corridor increases from 140 mG to 169 mG; and RCJ-23 corridor increases from 140 mG to 415 mG. Please note that the RCJ-22 corridor does not impact any existing residences as it crosses the Waterbury Reservoir.

CONCLUSION

The magnetic power frequency fields with the Lamoille Project for maximum loading directly under the power lines are expected to be on the order of 2.5 times less than the ICNIRP guideline of 833 mG and 25 times less than the IEEE guideline of 9,040 mG for public exposure. This demonstrates that the projected maximum magnetic power frequency fields directly under the power lines for the Lamoille Project are well below the health-based ICNIRP guideline.

SUMMARY

In summary, the projected magnetic power frequency fields with the Lamoille Project at the edge and in the ROW, at average or maximum loading, are less than the health-based ICNIRP guideline of 833 mG and the IEEE guideline of 9,040 mG for public exposure. The projected electric power frequency fields with the Lamoille Project are less than the health-based ICNIRP guideline of 4.2 kV/m and the IEEE guideline of 5 kV/m at the edge and in the ROW. This demonstrates that the projected electric and magnetic power frequency fields at the edge of the ROW and directly under the power line for the Lamoille Project are well below the health-based ICNIRP guidelines.

ELECTROMAGNETIC INTERFERENCE AND MEDICAL DEVICES

The American Conference of Governmental Industrial Hygienists (“ACGIH”) is the only organization that has issued guidelines for the exposure to EMF by people wearing medical devices. Specifically, the ACGIH guidelines refer only to “occupational” workers, such as electrical line workers, phone line workers, power station operators, welders, electricians, and electrical engineers. Occupational exposures to workers wearing cardiac pacemakers and medical electronic devices should not be exposed to: 1) magnetic power frequency fields exceeding 1,000 mG, and 2) electric power frequency fields exceeding 1 kV/m.

American Conference of Governmental Industrial Hygienists (ACGIH), 2004 [12]

“Some models of cardiac pacemakers have been shown to be susceptible to interference by power-frequency (50/60 Hz) magnetic flux densities as low as 0.1 mT (1,000 mG). It is recommended that, lacking specific information on electromagnetic interference from the manufacturer, the exposure of persons wearing cardiac pacemakers or similar medical electronic devices be maintained at or below 0.1 mT at power frequencies....Some models of cardiac pacemakers have been shown to be susceptible to interference by power-frequency (50/60 Hz) electric fields as low as 2 kV/m. It is recommended that, lacking specific information on electromagnetic interference from the manufacturer, the exposure of pacemaker and medical electronic device wearers should be maintained at or below 1 kV/m.”.

Excerpts from the literature include:

“The interference threshold of cardiac pacemakers depends in a complex way on a number of different factors such as: electromagnetic immunity and adjustment of the pacemaker, the composition of the applied low-frequency fields (only electric or magnetic fields or combinations of both), their frequencies and modulations, the type of pacemaker system (bipolar, unipolar) and its location in the body, as well as the body size and orientation in the field, and last but not least, certain physiologic al conditions of the patient (e.g. inhalation, exhalation).” [34]

“...it is possible under worst-case conditions but unlikely under practice-relevant conditions that an implanted cardiac pacemaker is disturbed by present electric 50 Hz fields beneath high voltage overhead lines.”[35]

“Use of bipolar mode confers a high degree of protection from extraneous electrical interference, but in unipolar mode pacemakers may be inhibited by small amounts of corporeal current, potentially encountered in every day life.”[36]

“Under certain circumstances, power-frequency electric and magnetic fields can interfere with implanted electronic medical devices...

...For the most part, these pacemaker and defibrillator anomalies are reversible, with the devices returning to normal operation upon removal of the electrical interference.

Depending on manufacturer and design, the magnetic field threshold for pacemaker interference (including the possibility of inappropriate pacing) is in the range of 2 to 12 G, and the electric field

threshold is about 1.5 kV/m for some of the newer and more sensitive dual-chamber units, and above 2 kV/m for current or older ventricular units.

...The ACGIH guidelines appear to be adequately protective of individuals who wear pacemakers. As well as can be determined, no pacemaker or defibrillator interference has been documented at those levels.”[37]

“Medical devices can usually be made much less susceptible to EMI if various considerations are incorporated during the initial design of the device. Shielding the electronics so that they are completely encased in an electrically-conductive enclosure can make medical devices highly immune to EM. Special filters are needed to keep EM voltages from being conducted through the shield from external input or output leads to the device...However, it is difficult to make filters that are effective at low frequencies while not compromising a medical device’s performance and safety requirements (maximum allowable leakage current from the lead to the case). In addition to hardware, well-designed software in these devices can recognize and minimize the effects of EMI.

...In perspective, the number of EMI incidents is very small even considering the vast amount of under-reporting that exists...”[38]

“A dedicated exposure system generated a 50-Hz frequency and maximum 100 microT (1000 mG) flux density, while the electrical field was kept at values on the order of 0.10 V/m...The overall incidence of interaction by a magnetic field was low in patients tested with a wide variety of conventionally programmed pacemaker models...The risk of interference appears negligible in patients with bipolar sensing programming.”[39]

“Many factors influence EMI including those which the patient can regulate (e.g., distance from and duration of exposure) and some the patient cannot control (e.g., intensity of the EMI field, signal frequency).”[40]

“Exposure was done to moderate (1.2-1.7 kV/m) and strong (7.0-8.0 kV/m) electric fields, which correspond to the immediate vicinity of 110 and 400 kV power lines, respectively...The results confirm that the programmed sensitivity level and the lead configuration markedly influence pacemakers’ vulnerability to EMI. Bipolar sensing mode is rather safe in the presence of EMI, which is encountered in public environments. The programmable features of today’s pacemakers permit individualized, less stringent safety measure to avoid electromagnetic hazards.”[41]

“Recommendation for patients implanted with pacemakers or ICDs

- Common household equipment – No special precautions for pacemaker and ICD patients in the use of microwaves or other common household equipment such as televisions, radios, toasters, and electric blankets.”[42] No mention is made of avoiding power lines.

“Q. Can I use power tools? A. Experience to date indicates that typical home power tools do not produce strong enough EMI/RFI to affect the operation of implantable pumps...

Q. Can I be near an electric substation? A. It is virtually impossible to know the amounts of interference present in a particular substation, and what amount of interference may affect a particular patient. There you should attempt to stay at least 25 feet from a substation to minimize the potential for these effects...If a change in stimulation occurs, you should move away from the substation until the stimulation returns to normal.”[43]

“Because the Iso Med Pump does not contain electronic circuitry, electrical devices will not affect it...If you suspect interference with your pump, move away from, or turn off, the electrical device. Your pump will not be permanently affected.”[44]

Examination of the U.S. Food and Drug Administration MedWatch [54] and MAUDE [55] databases and the National Library of Medicine [56], as of March 2005, did not identify any safety alerts, advisories, notices or adverse events identifying power line frequency EMF as a cause of medical device malfunction.

In 2015, the maximum electric and magnetic power frequency fields for the Lamoille Project will range from 0.72 to 2.54 kV/m, and 169 to 417 mG, respectively. These fields are based on calculations using the maximum continuous load rating, the maximum power line voltage, the minimum allowed height above the ground, and directly under the power line. The magnetic power frequency field, under these conditions, is projected to be approximately 2 to 4 times less than the ACGIH guideline of 1000 mG for occupational workers. The electric power frequency field, under these conditions, is projected to be higher than the ACGIH guideline of 1 kV/m. This type of condition is expected to occur very infrequently.

Under conditions of normal power use, at average loading and at the edge of the right of way, the magnetic power frequency field will range from 13 to 44 mG and the electric power

frequency field will range from 0.61 to 1.91 kV/m in 2015. It should be noted that the proposed height of the power lines is planned to be 5 feet higher or more than that assumed in this analysis. This increase in line height will reduce the electric power frequency field to levels below 1 kV/m [Prefiled Testimony of Peter A. Valberg, p. 21 of 26].

In summary, the VDH believes the projected electric and magnetic power frequency fields for the Lamoille Project at the edge and in the ROW are not likely to interfere with medical devices worn by the public. The projected electric and magnetic power frequency fields for the Lamoille Project are projected to be less than the ACGIH guidelines of 1 kV/m and 1000 mG at the edge of the ROW.

DOES THE VELCO TESTIMONY OF PETER A. VALBERG, PH.D. CORRESPOND WITH THE CURRENT SCIENTIFIC VIEW OF HUMAN EXPOSURE TO ELECTRIC AND MAGNETIC POWER FREQUENCY FIELDS?

The testimony provided by VELCO on the Lamoille Project and responses to questions in “VELCO, GMP and Stowe Response to Fourth Set of Information Requests” Docket No. 7032, March 14, 2005 and “VELCO, GMP and Stowe Response to Eighth Set of Information Requests” Docket No. 7032, March 28, 2005 corresponds with the current scientific view of human exposure to EMF.

CONCLUSIONS FOR THE LAMOILLE PROJECT

The Vermont Department of Health concludes that the electric and magnetic power frequency field strength for the Lamoille Project does not appear to be a public health hazard based on a review of the literature and on calculations with existing and projected current loads. In the absence of federal and state standards, the Vermont Department of Health applied the

Florida (150 mG, 2 kV/m), ICNIRP (833 mG, 4.2 kV/m) and IEEE (9,040 mG, 5 kV/m) guidelines for electric and magnetic power frequency fields to its analysis of the Lamoille Project.

The magnetic power frequency field for average loading at the edge of the ROW is projected to increase with the along the Lamoille Project corridor between 2006 and 2015 to less than 45 mG. This demonstrates that the projected magnetic power frequency fields at the edge of the ROW for the Proposed Reroutes are well below the health-based ICNIRP guideline of 833 mG.

The magnetic power frequency field for average loading directly under the power line is projected to increase along the Lamoille Project corridor between 2006 and 2015 to less than 45 mG. This demonstrates that the projected magnetic power frequency fields directly under the power line for the Proposed Reroutes are well below the health-based ICNIRP guideline of 833 mG.

The projected magnetic power frequency field for maximum continuous loading at the ROW edge for the Lamoille Project is 417 mG. This demonstrates that the projected maximum magnetic power frequency fields at the edge of the ROW for the Lamoille Project are well below the health-based ICNIRP guideline of 833 mG.

The projected magnetic power frequency field for maximum continuous loading directly under the power line for the Lamoille Project is 417 mG. This demonstrates that the projected maximum magnetic power frequency fields at the edge of the ROW for the Lamoille Project are well below the health-based ICNIRP guideline of 833 mG.

The electric power frequency fields at the edge of the ROW are projected to increase with the Lamoille Project. The electric power frequency fields for the Lamoille Project (0.61 to 1.91 kV/m) are projected to be less than the Florida guideline of 2 kV/m at the edge of the ROW. This demonstrates that the projected electric power frequency fields at the edge of the ROW for the Lamoille Project are well below the health-based ICNIRP guideline of 4.2 kV/m.

The electric power frequency fields directly under the power line are projected to increase with the Lamoille Project. The electric power frequency fields for the Lamoille Project are projected to be less than the Florida guideline of 8 kV/m (0.72 to 2.54 kV/m). This demonstrates that the projected electric power frequency fields directly under the power line for the Lamoille Project are well below the health-based ICNIRP guideline of 4.2 kV/m.

In summary, the projected magnetic power frequency fields at the edge of the ROW and directly under the power line for average and maximum continuous load with the Lamoille Project are less than the health-based ICNIRP guideline of 833 mG. The projected electric power frequency fields at the edge of the ROW and directly under the power line for average maximum continuous load with the Lamoille Project are less than the ICNIRP guideline of 4.2 kV/m. This demonstrates that the projected electric and magnetic power frequency fields for the Lamoille Project are well below the health-based ICNIRP guidelines at the edge of the ROW and directly under the power line.

It should be noted that the electric and magnetic power frequency fields are similar in magnitude to those determined for the Northwest Vermont Reliability Project.

The Vermont Department of Health concludes that modifications to the Lamoille Project are not required for health reasons, but Vermont's policy of prudent avoidance to mitigate EMF exposure as identified in the Vermont Twenty Year Electric Plan (1994) should be continued.

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APPENDIX A

DATA FROM VELCO

Table 1. Proposed Electric & Magnetic Field Input Data								
RCJ 18								
This is the field input data for proposed double 115 kV lines from the Duxbury Tap to the Duxbury Switching Station (~0.33 mi).								
Bundle	x-feet	y-feet	n cond	Cond D	Bund D	I-n volt	phase	
1	-17	35.1	1	1.345	NA ¹	69.72	0	
2	-33	27.6	1	1.345	NA	69.72	240	
3	-15	20.1	1	1.345	NA	69.72	120	
4	17	35.1	1	1.345	NA	69.72	0	
5	33	27.6	1	1.345	NA	69.72	120	
6	15	20.1	1	1.345	NA	69.72	240	
RCJ 19								
This is the field input data for proposed 115kV line from the Duxbury Switching Station to North of Interstate 89 (~0.43 mi).								
Bundle	x-feet	y-feet	n cond	Cond D	Bund D	I-n volt	phase	
1	-7	20.1	1	1.345	NA	69.72	0	
2	0	20.1	1	1.345	NA	69.72	240	
3	7	20.1	1	1.345	NA	69.72	120	
RCJ 20								
This is the field input data for proposed 115kV line from North of Interstate 89 to Waterbury Center Tap (~2.88 mi).								
Bundle	x-feet	y-feet	n cond	Cond D	Bund D	I-n volt	phase	
1	-8.12	35.1	1	1.345	NA	69.72	0	
2	8.17	27.6	1	1.345	NA	69.72	240	
3	-11.22	20.1	1	1.345	NA	69.72	120	

RCJ 21

This is the field input data for proposed 115kV line and 34.5 kV line from Waterbury Center Tap to 0.2 Mile North of Moscow Substation (~4.81 mi).

Bundle	x-feet	y-feet	n cond	Cond D	Bund D	L-n volt	phase
1	8.12	35.1	1	1.345	NA	69.72	0
2	-8.17	27.6	1	1.345	NA	69.72	240
3	11.22	20.1	1	1.345	NA	69.72	120
4	-20.42	18.5	1	0.721	NA	20.9	0
5	-25	19.5	1	0.721	NA	20.9	240
6	-29.58	18.5	1	0.721	NA	20.9	120

RCJ 22

This is the field input data for proposed 115kV line and 34.5 kV line crossing Waterbury Reservoir.

Bundle	x-feet	y-feet	n cond	Cond D	Bund D	L-n volt	phase
1	11	39	1	1.345	NA	69.72	0
2	25	39	1	1.345	NA	69.72	240
3	39	39	1	1.345	NA	69.72	120
4	-40	39	1	0.721	NA	20.9	240
5	-50	39	1	0.721	NA	20.9	0
6	-60	39	1	0.721	NA	20.9	120

RCJ 23

This is the field input data for proposed 115kV line and 34.5 Double Circuit from 0.2 Mile North of Moscow Substation to the Stowe Substation (~1.10 mi).

Bundle	x-feet	y-feet	n cond	Cond D	Bund D	L-n volt	phase
1	8.12	35.1	1	1.345	NA	69.72	0
2	-8.17	27.6	1	1.345	NA	69.72	240
3	11.22	20.1	1	1.345	NA	69.72	120
4	-21.38	33.5	1	0.721	NA	20.9	0
5	-20.73	26	1	0.721	NA	20.9	240
6	-21.31	18.5	1	0.721	NA	20.9	120
7	-28.62	33.5	1	0.721	NA	20.9	120
8	-29.27	26	1	0.721	NA	20.9	240
9	-28.69	18.5	1	0.721	NA	20.9	0

Notes: *X-feet, N-cond, Cond-D, Bund D, L-n voltage, and phase from e-mail of Jeff Carrara, March 24, 2005.

*Y-feet for the proposed structures are based on the minimum NESC conductor height above ground from the Response to Fourth Set of Information Requests Served by the Department of Public Service, and per e-mail of Jeff Carrara, March 24, 2005.

¹NA = not applicable

APPENDIX B

Table 1.

MAGNETIC POWER FREQUENCY FIELD STRENGTH AT AVERAGE LOADING ON THE EDGE OF THE RIGHT OF WAY¹

(milliGauss)

Corridor	Existing Power Line				Proposed Power Line			
	2006	2009	2012	2015	2006	2009	2012	2015
RCJ 18	NA ²	NA	NA	NA	17	19	20	21
RCJ 19	3.6	4.1	4.5	5.1	11	12	13	14
RCJ 20	3.6	4.1	4.5	5.1	16	18	19	20
RCJ 21	17	20	22	22	16	17	19	20
RCJ 22	17	20	22	22	11	12	12	13
RCJ 23	4.4	3.1	2.7	1.8	27	34	39	44

RCJ 18 = Duxbury Tap to Duxbury Switching Station

RCJ 19 = Duxbury Switching Station to North of Interstate 89

RCJ 20 = North of Interstate 89 to Waterbury Center Tap

RCJ 21 = Waterbury Center Tap to North of Moscow Substation

RCJ 22 = Waterbury Reservoir Crossing

RCJ 23 = North of Moscow Substation to Stowe Substation

¹40 foot ROW for all corridors

²NA = no power line presently in this corridor

Table 2.

MAGNETIC POWER FREQUENCY FIELD STRENGTH AT AVERAGE LOADING DIRECTLY UNDER THE POWER LINE

Corridor	Existing Power Line				Proposed Power Line			
	2006	2009	2012	2015	2006	2009	2012	2015
RCJ 18	NA ¹	NA	NA	NA	17	19	20	22
RCJ 19	9.0	10	11	13	23	25	27	28
RCJ 20	9.0	10	11	13	23	25	26	28
RCJ 21	43	49	53	54	23	25	27	28
RCJ 22	43	49	53	54	11	12	12	13
RCJ 23	11	8	7	5	27	34	39	44

RCJ 18 = Duxbury Tap to Duxbury Switching Station

RCJ 19 = Duxbury Switching Station to North of Interstate 89

RCJ 20 = North of Interstate 89 to Waterbury Center Tap

RCJ 21 = Waterbury Center Tap to North of Moscow Substation

RCJ 22 = Waterbury Reservoir Crossing

RCJ 23 = North of Moscow Substation to Stowe Substation

¹NA = no power line presently in this corridor

Table 3.

**MAGNETIC POWER FREQUENCY FIELD STRENGTH AT MAXIMUM CONTINUOUS RATED LOAD
DIRECTLY UNDER THE POWER LINE AND AT THE EDGE OF THE RIGHT OF WAY**

(milliGauss)

Corridor	Existing Power Line		Proposed Power Line	
	Directly Under	ROW Edge¹	Directly Under	ROW Edge¹
RCJ 18	NA ²	NA	417	417
RCJ 19	80	33	358	177
RCJ 20	80	33	358	259
RCJ 21	140	57	361	251
RCJ 22	140	57	169	169
RCJ 23	140	57	415	392

RCJ 18 = Duxbury Tap to Duxbury Switching Station

RCJ 19 = Duxbury Switching Station to North of Interstate 89

RCJ 20 = North of Interstate 89 to Waterbury Center Tap

RCJ 21 = Waterbury Center Tap to North of Moscow Substation

RCJ 22 = Waterbury Reservoir Crossing

RCJ 23 = North of Moscow Substation to Stowe Substation

¹40 foot ROW for all corridors

²NA = no power line presently in this corridor

Table 4.

**ELECTRIC POWER FREQUENCY FIELD STRENGTH AT MAXIMUM OR AVERAGE CONTINUOUS RATED LOAD
DIRECTLY UNDER THE POWER LINE AND AT THE EDGE OF THE RIGHT OF WAY**

(kilovolt/meter)

Corridor	Existing Power Line		Proposed Power Line	
	Directly Under	ROW Edge¹	Directly Under	ROW Edge¹
RCJ 18	NA ²	NA	2.54	1.91
RCJ 19	0.32	0.23	1.58	1.33
RCJ 20	0.32	0.23	2.18	1.85
RCJ 21	0.39	0.27	2.19	1.86
RCJ 22	0.39	0.27	0.72	0.61
RCJ 23	0.39	0.27	2.11	1.80

RCJ 18 = Duxbury Tap to Duxbury Switching Station

RCJ 19 = Duxbury Switching Station to North of Interstate 89

RCJ 20 = North of Interstate 89 to Waterbury Center Tap

RCJ 21 = Waterbury Center Tap to North of Moscow Substation

RCJ 22 = Waterbury Reservoir Crossing

RCJ 23 = North of Moscow Substation to Stowe Substation

¹40 foot ROW for all corridors

²NA = no power line presently in this corridor

Table 5.

**DISTANCE FROM CENTER OF RIGHT OF WAY AT WHICH MAGNETIC POWER
FREQUENCY FIELD HAS DROPPED TO 4 MILLIGAUSS AT AVERAGE LOADING
(feet)**

Corridor	Existing Power Line				Proposed Power Line			
	2006		2015		2006		2015	
	West	East	West	East	West	East	West	East
RCJ 18	NA ¹	NA	NA	NA	75	75	83	83
RCJ 19	18	18	22	22	40	40	44	44
RCJ 20	18	18	22	22	52	49	58	53
RCJ 21	48	48	56	56	47	50	56	56
RCJ 22	48	48	56	56	53	73	65	83
RCJ 23	21	21	5	5	83	61	97	73

RCJ 18 = Duxbury Tap to Duxbury Switching Station

RCJ 19 = Duxbury Switching Station to North of Interstate 89

RCJ 20 = North of Interstate 89 to Waterbury Center Tap

RCJ 21 = Waterbury Center Tap to North of Moscow Substation

RCJ 22 = Waterbury Reservoir Crossing

RCJ 23 = North of Moscow Substation to Stowe Substation

¹NA = no power line presently in this corridor

Table 6.

MAGNETIC POWER FREQUENCY FIELD STRENGTH AT IDENTIFIED BUILDINGS NEAR THE RIGHT OF WAY AT AVERAGE LOADING

(milliGauss)

Corridor	Road	Mile	Pole	Distance ¹ (feet)	Existing Power Line		Proposed Power Line		
					2006	2015	2006	2015	
RCJ-19	River Road	0.10	3	600 E	< 2	< 2	< 2	< 2	
	North Main Street	0.33	6	150 E	< 2	< 2	< 2	< 2	
RCJ-20	Blackberry Lane	0.77	13	225 W	< 2	< 2	< 2	< 2	B ²
	Ashcroft Lane	0.89	14	50 E	< 2	< 2	3.7	4.6	
		0.89	14	130 E	< 2	< 2	< 2	< 2	
		0.91	14	150 E	< 2	< 2	< 2	< 2	
	Acorn Drive	0.95	15	50 E	< 2	< 2	3.7	4.6	
		1.10	17	450 E	< 2	< 2	< 2	< 2	
	Blush Hill Road	1.12	18	75 E	< 2	< 2	< 2	2.3	
		1.16	18	55 E	< 2	< 2	3.2	3.9	
	Cross Road	1.39	22	185 E	< 2	< 2	< 2	< 2	
		1.43	22	110 E	< 2	< 2	< 2	< 2	
		1.45	23	300 W	< 2	< 2	< 2	< 2	
	Meadow Crest Drive	1.47	23	165 E	< 2	< 2	< 2	< 2	
		1.51	23	75 E	< 2	< 2	< 2	2.3	
		1.58	25	300 W	< 2	< 2	< 2	< 2	
		1.59	25	110 E	< 2	< 2	< 2	< 2	
		1.66	26	300 W	< 2	< 2	< 2	< 2	
		1.67	27	75 E	< 2	< 2	< 2	2.3	
	Countryside Road	1.95	31	335 E	< 2	< 2	< 2	< 2	
	Blush Hill Road ³	2.35	37	525 W	< 2	< 2	< 2	< 2	
		2.40	37	300 W	< 2	< 2	< 2	< 2	
	Blush Hill Estates	2.45	38	375 E	< 2	< 2	< 2	< 2	
	Blush Hill Road	2.93	47	20 W	2.4	5.0	16	20	
		2.93	47	150 W	< 2	< 2	< 2	< 2	
		3.00	48	225 W	< 2	< 2	< 2	< 2	
		3.07	49	110 W	< 2	< 2	< 2	< 2	

RCJ-21	Waterbury Reservoir	3.37	53	54 E	3.3	4.2	3.2	4.1
		3.45	54	150 E	< 2	< 2	< 2	< 2
		3.45	54	110 W	< 2	< 2	< 2	< 2
RCJ-21	Gregg Hill Road	4.25	65	280 W	< 2	< 2	< 2	< 2
		4.27	65	150 W	< 2	< 2	< 2	< 2
		4.28	66	225 E	< 2	< 2	< 2	< 2
		4.38	68	110 W	< 2	< 2	< 2	< 2
		4.60	72	375 W	< 2	< 2	< 2	< 2
		4.87	76	335 W	< 2	< 2	< 2	< 2
		5.00	79	410 W	< 2	< 2	< 2	< 2
		5.67	90	300 W	< 2	< 2	< 2	< 2
		5.92	94	95 E	< 2	< 2	< 2	< 2
		6.05	96	150 E	< 2	< 2	< 2	< 2
	Stoneledge Lane	6.12	97	55 W	3.3	4.2	3.2	4.1
	Gregg Hill Road	6.40	102	75 E	< 2	2.3	< 2	2.3
		6.45	102	75 E	< 2	2.3	< 2	2.3
		6.55	104	360 E	< 2	< 2	< 2	< 2
	Waterbury-Stowe Road	6.77	107	395 E	< 2	< 2	< 2	< 2
	Black Bear Run	6.87	109	35 W	7.5	9.5	6.4	8.2
		7.00	110	110 W	< 2	< 2	< 2	< 2
		7.02	111	75 E	< 2	2.3	< 2	2.3
	Waterbury-Stowe Road	7.05	111	30 W	9.6	12	7.6	9.5
		7.06	111	415 E	< 2	< 2	< 2	< 2
		7.10	112	320 W	< 2	< 2	< 2	< 2
		7.14	113	260 W	< 2	< 2	< 2	< 2
		7.17	113	150 W	< 2	< 2	< 2	< 2
		7.25	115	319 E	< 2	< 2	< 2	< 2
		7.32	116	75 W	< 2	2.3	< 2	2.3
	South Marshall Road	7.34	116	70 W	2.1	2.7	2.1	2.6
		7.35	116	110 E	< 2	< 2	< 2	< 2
		7.37	117	35 W	7.5	9.5	6.4	8.2
		7.39	117	225 E	< 2	< 2	< 2	< 2
	Marshall Road	7.47	119	130 E	< 2	< 2	< 2	< 2
		7.52	119	170 E	< 2	< 2	< 2	< 2
	Moscow Road	7.69	123	55 W	3.3	4.2	3.2	4.1
	River Road	8.11	129	95 W	< 2	< 2	< 2	< 2

B

RCJ-23	River Road	8.15	129	260 W	< 2	< 2	< 2	< 2
	Shaw Hill Road	8.36	133	225 W	< 2	< 2	< 2	< 2
	East Shaw Hill Road ³	8.46	135	270 W	< 2	< 2	< 2	< 2
		8.53	136	95 W	< 2	< 2	2.9	4.4
		8.79	148	225 E	< 2	< 2	< 2	< 2
	River Road	8.79	148	225 E	< 2	< 2	< 2	< 2
		8.91	145	215 E	< 2	< 2	< 2	< 2
	Holmes Lane	8.97	147	220 W	< 2	< 2	< 2	< 2
		9.00	147	50 W	< 2	< 2	12	18
		9.01	148	50 E	< 2	< 2	5.5	7.6
		9.06	148	320 E	< 2	< 2	< 2	< 2
	River Road	9.11	149	300 E	< 2	< 2	< 2	< 2
	Cady Hill Road	9.16	150	95 E	< 2	< 2	< 2	2.6
		9.19	151	95 E	< 2	< 2	< 2	2.6
		9.23	152	19 E	4.4	< 2	15	18
		9.23	152	260 E	< 2	< 2	< 2	< 2
		9.33	153	150 E	< 2	< 2	< 2	< 2
		9.34	153	95 E	< 2	< 2	< 2	< 2
		9.38	155	130 E	< 2	< 2	< 2	< 2
		9.38	155	300 E	< 2	< 2	< 2	< 2

RCJ 18 = Duxbury Tap to Duxbury Switching Station

RCJ 19 = Duxbury Switching Station to North of Interstate 89

RCJ 20 = North of Interstate 89 to Waterbury Center Tap

RCJ 21 = Waterbury Center Tap to North of Moscow Substation

RCJ 22 = Waterbury Reservoir Crossing

RCJ 23 = North of Moscow Substation to Stowe Substation

¹Distance is from center of ROW

²B = Business

³Distance from 115 kV line